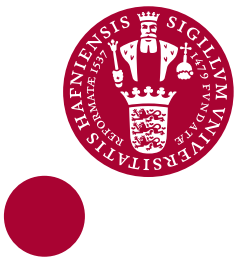

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Ocean anoxia and large igneous provinces

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Earth's history is marked by multiple events of ocean anoxia developing along continental margins and potentially into the open ocean realm. These events often coincide with the emplacement of large igneous provinces (LIPs) on continents, major perturbations of global geochemical cycles and marine (mass) extinction. The geographic and temporal extend and the intensity (ferruginous vs. euxinic) of anoxic conditions is often, however, poorly constraint. This complicates understanding of close coupling between Earth's physical, chemical and biological processes. We studied ocean redox change over two major mass extinction events in Earth history, the Permian-Triassic (at ∼252 Ma) and Triassic-Jurassic (at ∼201.3 Ma) mass extinctions. Both extinction events are marked by a major perturbation of the global exogenic carbon cycle (and associated major negative carbon isotope excursion (CIE)), likely initiated by carbon outgassing of the Siberian Traps and the Central Atlantic Magmatic Province (CAMP), respectively. We compare Permian-Triassic and Triassic-Jurassic ocean redox change along continental margins in different geographic regions (Permian-Triassic: Greenland, Svalbard, Iran; Triassic-Jurassic: UK, Austria) and discuss its role in marine mass extinction.

We show strongly enhanced sedimentary redox-sensitive trace element concentrations (e.g. Mo) during both events. However, increased Permian-Triassic values are in all localities distinctly delayed relative to the associated negative CIE. Triassic-Jurassic values are only delayed in the oceanographically restricted western Germanic basin (UK) while increased Mo-values in the north-western Tethys Ocean (Austria) directly match the onset of the associated negative CIE.

Speciation of iron [giving (Fe-HR/ Fe-T) and (Fe(Py)/ Fe-HR)] in the Triassic-Jurassic western Germanic basin (UK) however shows close coupling between the onset of the global carbon cycle perturbation and a shift to anoxic and even euxinic conditions. Delayed molybdenum enrichment in this basin suggests strong initial depletion of the molybdenum reservoir. Triassic-Jurassic molybdenum drawdown does however occur in more well-connected marine basins along continental margins. Iron speciation and delayed Mo-enrichments along Permian-Triassic continental margins in different geographic regions suggest more widely, potentially global ocean, molybdenum drawdown and more widespread ocean anoxia. Further, our data shows that anoxic (and euxinic) conditions directly matches extinction of marine organisms, suggesting ocean anoxia as contributor to marine ecosystem collapse.